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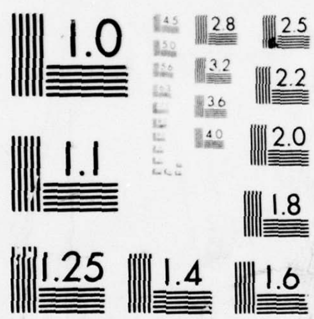

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NATIONAL BUREAU OF STANDARDS-1963-A

Report SAM-TR- 77-9

VCG MEASUREMENT AND DISPLAY

July 1977

Final Report for Period January-October 1976

Approved for public release; distribution unlimited.

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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Obtaining measurements from patient vectorcardiograms is a tedious and time-consuming procedure. This report describes a computer-assisted method to derive the interval amplitude and angular measurements used by vectorcardiologist to evaluate a patient vectorcardiogram. The computer also prepares graphic displays which have much better resolution than the conventional Polaroid photographs. All measurements are made on the same beat rather than having each planar projection and loop from a different beat as in the photographic method.

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VCG MEASUREMENT AND DISPLAY

INTRODUCTION

Aircrewmen referred to the USAF School of Aerospace Medicine have a vectorcardiogram (VCG) taken as part of their routine evaluation. The x, y, and z lead signals are recorded as frequency-modulated (FM) signals on analog magnetic tape, and conventional Polaroid photographs are taken of the VCG loops. These data are then made available to research cardiologists through a system which digitizes, filters, and measures the data to provide parameters that previously were manually derived. The digitizing and filtering portion of the system has been documented (11).

This report defines the computer algorithms that provide VCG measurements for the cardiologist. These algorithms require VCGs that have been baseline adjusted and converted to millivolts. Most of these measurements are the ones normally derived by cardiologists for clinical evaluation. Some additional measurements, which are more difficult for the human to obtain, are provided to assist in the cardiologist's evaluation and for investigational purposes; e.g., identifying specific features to use in an automated VCG analysis.

The conventional Polaroid photographs provided by the VCG equipment used at USAFSAM (6) display data at 2.5-msec intervals, or 400 samples/sec. The data acquired by the digitizing system are sampled every 2 msec, or 500 samples/sec. To provide displays comparable to the photographs, the digitized data are linearly interpolated to provide an effective sampling rate of 400 samples/sec. In the Polaroid photographs, each sample is presented as a teardrop to assist in identification and to determine direction of motion. Our system represents each interpolated sample as a plus sign which increases in size with time.

VECTOR DEFINITIONS

The computer algorithms use several vectors and their length. For clarity and accuracy, the following convention will be used. When vectors are referenced, the symbols will be underlined; when the vector length is referenced, the symbol will not be underlined. For example, the heart vector, $\underline{h}(t)$, whose components are the x, y, and z lead signals for time (t):

$$\underline{h}(t) = \begin{bmatrix} x(t) \\ y(t) \\ z(t) \end{bmatrix}$$

and its length, h(t):

$$h(t) = \sqrt{\underline{h}^T(t)\ \underline{h}(t)} = \sqrt{x(t)^2 + y(t)^2 + z(t)^2}\ .$$

The time derivative of the heart vector (the velocity vector) and its length are defined as $\underline{VV}(t)$ and $VV(t)$, where

$$\underline{VV}(t) = d\ \underline{h}(t)/dt = \begin{bmatrix} dx(t)/dt \\ dy(t)/dt \\ dz(t)/dt \end{bmatrix}$$

and

$$VV(t) = \sqrt{\underline{VV}^T\ (t)\ \underline{VV}(t)} = \sqrt{(dx(t)/dt)^2 + (dy(t)/dt)^2 + (dz(t)/dt)^2}$$

Figure 1 shows the velocity vector, $\underline{VV}(t)$, partitioned into two components: one, $\underline{VV}_{11}(t)$, parallel to the heart vector; and the other, $\underline{VV}_{\perp}(t)$, perpendicular to it. These two components represent the derivative of the heart vector resulting from stretching and swinging. When the heart vector remains constant in length and rotates, $\underline{VV}_{11}(t) = 0$. When the heart vector remains fixed in space and lengthens or shortens, $\underline{VV}_{\perp}(t) = 0$. Finally, it can be shown that the length of $\underline{VV}_{11}(t)$, which we designate $VV_{11}(t)$, is the time derivative of the length of the heart vector:

$$VV_{11}(t) = dh(t)/dt$$

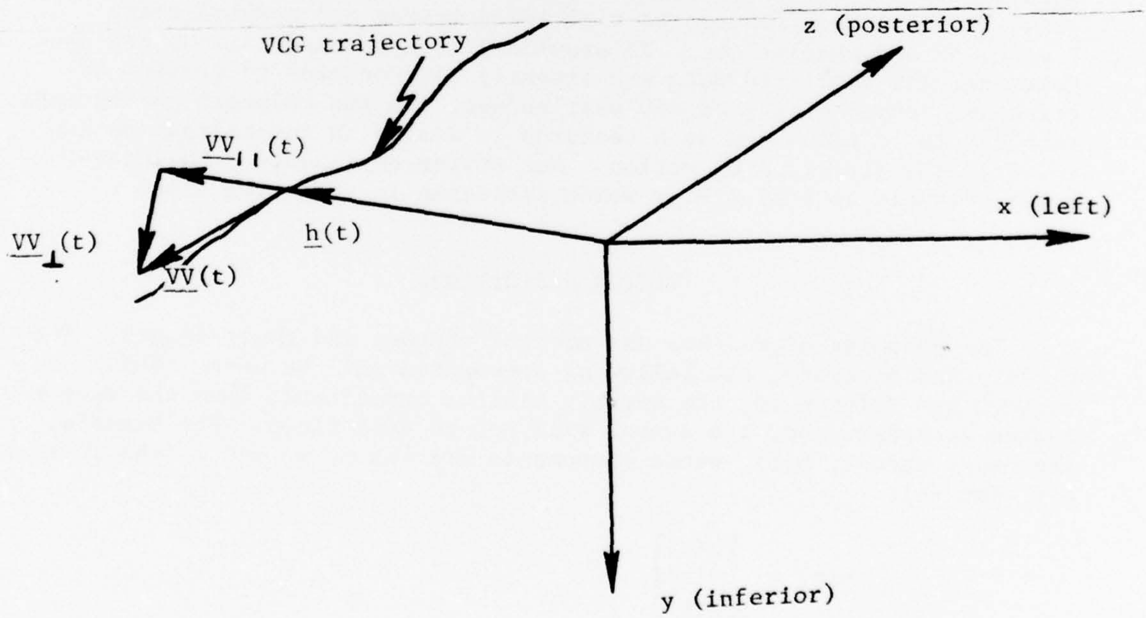


Figure 1. Example of the velocity vector.

The incremental heart vector is the change in the heart vector from one sample to the next.

$$S\underline{h}(k) = \underline{h}(k) - \underline{h}(k-1) = \begin{bmatrix} x(k) - x(k-1) \\ y(k) - y(k-1) \\ z(k) - z(k-1) \end{bmatrix}$$

where k signifies the kth sample. All velocity vectors are approximated by incremental vectors, which means that the velocity vector approximations are measured in mV/sample (2.5 msec) rather than mV/msec.

Two mean QRS vectors are measured. The first is the usual (standard) mean QRS vector, QRS_{mean}, whose components are obtained from the individual signals (4). In the x and y leads, the usual mean QRS values are defined as the algebraic sum of the amplitudes of the signal at the minimum of the Q wave and maximum of the R wave (see Fig. 2). In the (-z) lead, the usual mean QRS values are defined as the sum of the amplitudes of the signal at the maximum of the R wave and the minimum of the S wave (see Fig. 3). If any of the waves do not exist in a particular lead, the value of the amplitude is assumed to be zero. After the components are determined, the usual mean QRS vector is assembled.

$$QRS_{mean} = \begin{bmatrix} QRS_{mean}(x) \\ QRS_{mean}(y) \\ QRS_{mean}(z) \end{bmatrix}$$

The second mean QRS vector measured is designated the true mean QRS vector (1, 4). It is a vector along the vector mean of all the heart vectors comprising the QRS loop.

$$QRS_{mean} = \sum_{k=N_Q}^{N_J} \begin{bmatrix} x(k) \\ y(k) \\ z(k) \end{bmatrix} / (N_J - N_Q + 1)$$

where N_Q and N_J are the indexes at which the QRS loop begins and ends, respectively. Figure 4 shows an example of the true mean QRS vector.

The true mean QRS vector can also be viewed in another manner. Consider the x lead shown in Figure 5. The area under the QRS wave can be approximated by the area enclosed in the rectangles (7).

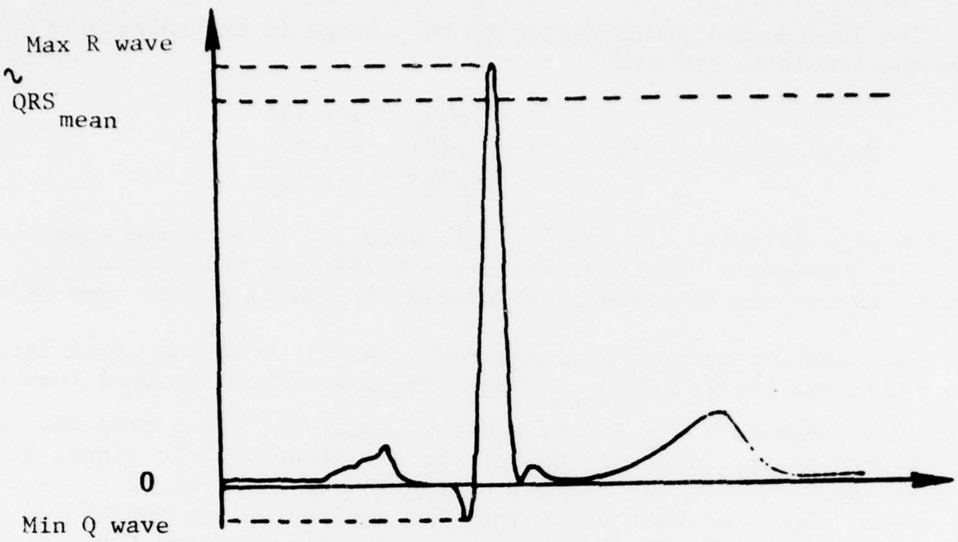


Figure 2. Definitions used for the usual mean QRS values in x and y leads.

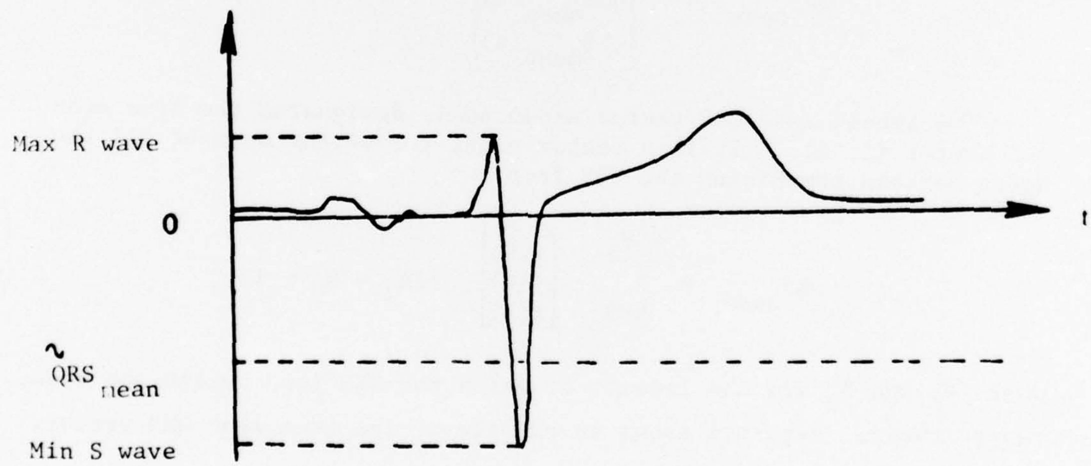


Figure 3. Definition used for the usual mean QRS values in the z lead.

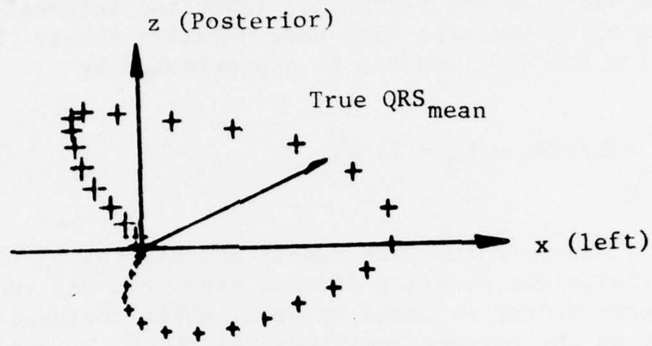


Figure 4. An example of the true mean QRS vector.

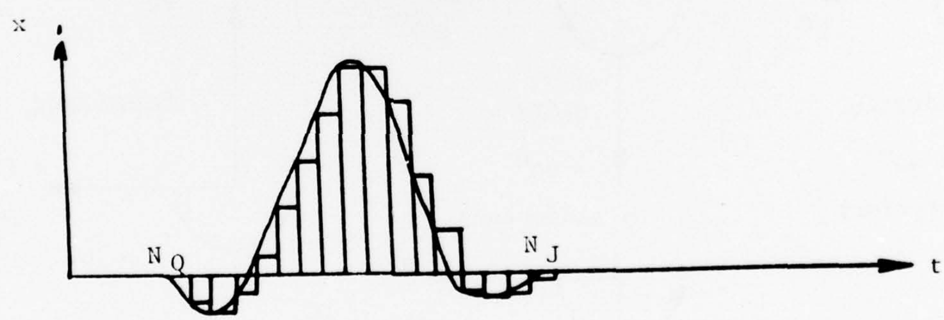


Figure 5. Example of true mean calculation.

This can be

$$A = \sum_{k=N_Q}^{N_J} x(k)\ \Delta T = \Delta T \sum_{k=N_Q}^{N_J} x(k)$$

where ΔT is the width of the rectangles (sampling interval). Observe that rectangles below the zero line have negative areas. The average value of x during the QRS loop can be approximated by

$$\Delta T \sum_{k=N_Q}^{N_J} x(k)/(N_J - N_Q + 1)\ \Delta T$$

Treating leads y and z in the same manner and assembling the results into a vector yields the equation for the true mean QRS vector. Therefore the true mean vector is based on area, while the usual mean vector is based merely on the extreme amplitudes of the Q, R, and S waves.

The vectors measured are presented to the cardiologists as projections into four planes--frontal, left-sagittal, transverse, and eigen. When the values of these planar projections are identified for examination, polar coordinates will be used. The references for and positive directions of the angles are given in Figure 6. The angles are always less than 180° (+ 270° is presented as its equivalent - 90°, etc.)

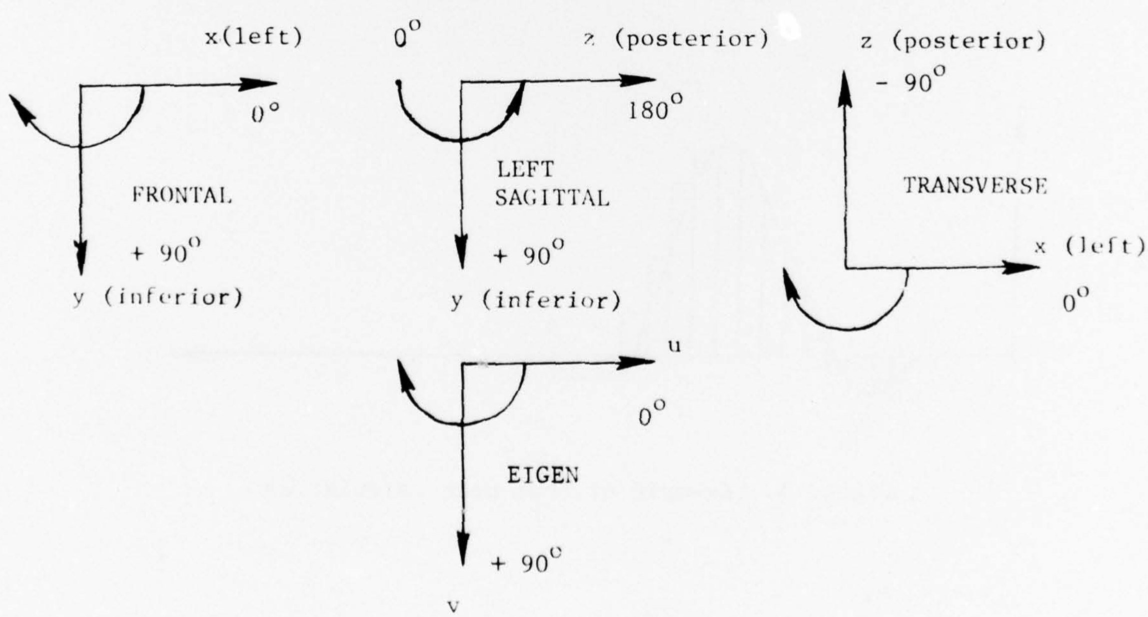


Figure 6. Examples of angular measurement in the various planes.

POINT DEFINITIONS AND EXAMPLES

The first task of the measurement portion of the routine is to identify one heart beat. This is performed by locating a fiducial point on each R wave. This fiducial point is designated as the N_Fth sample and is used to define a window of interest 1 sec or the mean RR interval, whichever is shorter, in length. This window is positioned so that 45% of it occurs before N_F and 55% occurs after. These percentages are empirically chosen after examination of more than 1,000 vectorcardiograms. This fiducial point is defined as the sample corresponding to the maximum velocity vector.

The x, y, and z lead data have been previously processed to define a zero reference and adjust all data to it (12); however, the zero-reference definition in the preprocessor is a weighted sum of the TP and PR segments. A decision to use the PR segment as the zero-reference was made because USAFSAM cardiologists plan to use these algorithms with data obtained at higher heart rates, such as those during exercise. Therefore, this zero reference is shifted from the commonly used TP segment. Since the PR segment is sloped in many cases, a more precise definition is required for the amplitude measurement reference point. After examining more than 1,000 VCGs, a decision was made to define the PR segment as follows. The 150-msec interval (61 samples) of the velocity vector data prior to the fiducial is searched to determine the 15-msec segment of least activity. The average value of the heart vector for that 15-msec segment is defined as the zero-reference value. This region of least activity is defined as the 15-msec segment of data for which the average velocity vector is a minimum (see Fig. 7).

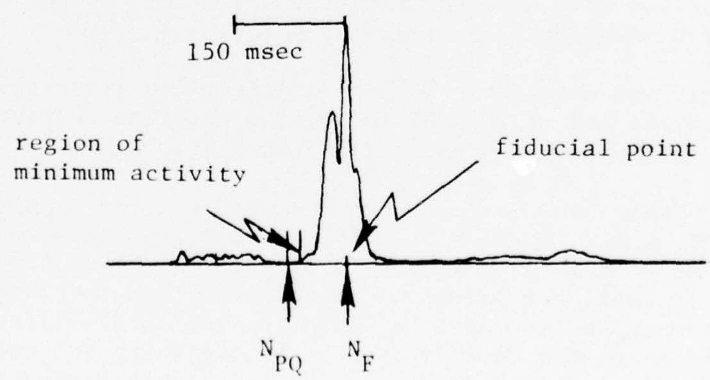


Figure 7. Determination of the 15-msec baseline interval (N_{PQ}).

The computer algorithm for determining the 15-msec zero-reference segment finds a minimum for

$$\sum_{k=i}^{i+6} VV(k)$$

when i ranges from the (N_F - 60th) to the (N_F - 6th) sample. The first sample of this segment is defined as N_{PQ}. The zero-reference point is then defined as

$$\begin{bmatrix} x_{bl} \\ y_{bl} \\ z_{bl} \end{bmatrix} = {}^1/_7 \sum_{k=0}^{6} \begin{bmatrix} x(N_{PQ} + k) \\ y(N_{PQ} + k) \\ z(N_{PQ} + k) \end{bmatrix}$$

To agree with the measurements obtained by the cardiologists, the origin of the Frank coordinate system is adjusted to this zero reference by

$$\begin{bmatrix} x(k) \\ y(k) \\ z(k) \end{bmatrix} = \begin{bmatrix} x(k) - x_{bl} \\ y(k) - y_{bl} \\ z(k) - z_{bl} \end{bmatrix} \quad ; k = 1, 2, \ldots\ldots, N_B$$

where N_B is the number of samples in the beat.

Similar logic is used to determine the beginning and ending points of the three loops (P, QRS, and T) examined by cardiologists. First a region of interest is defined for each:

(1) For the P loop, the time interval (N_{PQ}) from the beginning of the beat to the beginning of the PR segment.

(2) For the QRS loop, the time interval from the end of the PR segment to 100 msec after the fiducial point.

(3) Only the end of the T loop is determined (its beginning is defined to be the end of the QRS loop) from the time interval between the end of the QRS loop and the end of the beat.

In each region of interest, the maximum velocity-vector length, VV, is determined, and a threshold is defined as a predetermined percent of this maximum. A 10-msec window (5 samples) is moved forward from the maximum VV until all points in it are less than the threshold. A second 10-msec window is moved backward in time until all VV values are less than the threshold (see Fig. 8). The beginning and ending of the loops are defined as the rightmost point in the backward-moving window and the leftmost in the forward-moving window.

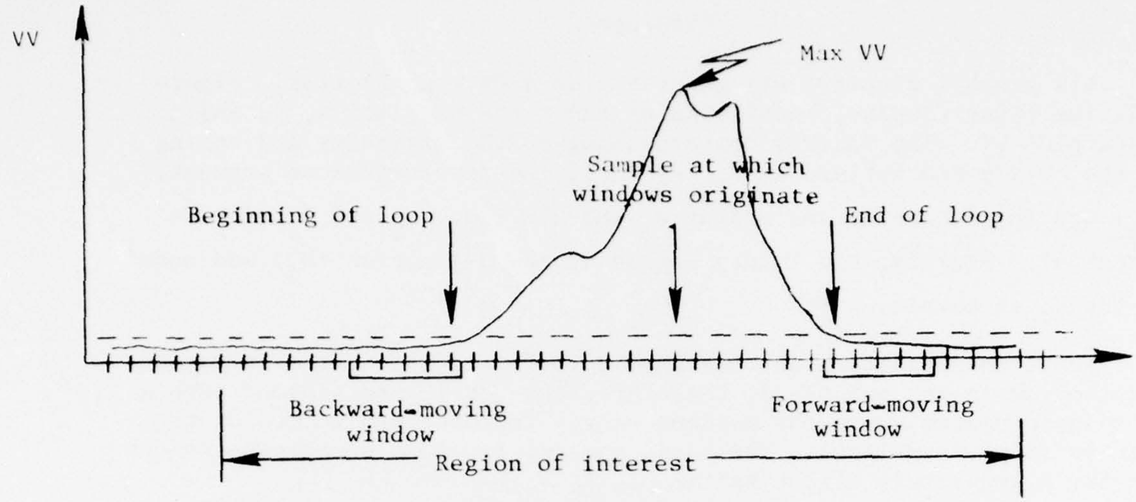


Figure 8. An example of the loop-finding algorithm.

This loop-defining algorithm works well in most cases; however, there are exceptions. To handle some of these, the algorithm includes the following additional rules.

P Loop

If the duration of the P wave is greater than 150 msec, the threshold is raised by 10% of the maximum VV and the process is repeated. If necessary, this incrementing is continued until the criteria are satisfied or the threshold reaches 50% of the maximum VV. If the latter occurs, a flag is set and processing continues for the next measurement.

QRS Loop

If the threshold criteria are not satisfied for the beginning of the QRS loop, the beginning is defined as the end of the zero-reference segment (N_{PQ} + 6th sample). Likewise, if the criteria for the ending are not satisfied within 100 msec after the fiducial point, the ending is defined as 100 msec after the fiducial (N_F + 40th sample).

T Loop

If the threshold criteria are not satisfied for the ending window, the threshold is raised in increments of 10% of the maximum VV, and the procedure is repeated until either the criteria are satisfied or the threshold reaches 50% of the maximum VV. In the latter case, a flag is set and processing continues.

Displays

All graphic displays are generated on a Calcomp Plotter. Figure 9 is the first display, consisting of the three original x, y, and z leads plus $\overline{VV}$. The indexes corresponding to the beginning and ending of the P loop are defined as N_{PB} and N_{PE}; the zero-reference segment, N_{PQ}; and the beginning and ending of the QRS loop, N_Q and N_J (for J-junction). Finally, the T loop begins at the J-junction (N_J) and ends at the N_{TE}th sample.

Next, investigators at USAFSAM (1, 7, 9) are interested in examining the VCG in its own plane; therefore, the VCG is transformed into a coordinate system where the maximum energy is contained in two of the signals (the eigenplane). The basis vectors for this coordinate system are the eigenvectors of the matrix (2, 3, 5, 10, 11, 13, 14).

$$\sum_{i=1}^{N_B} \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} \begin{bmatrix} x_i & y_i & z_i \end{bmatrix}$$

Because the eigenvectors' directions are not unique, and in order to agree with the work of the others (7-9, 11), the basis vectors are rotated about the out-of-eigenplane vector so that the final basis vectors (U, V, and W) have the following orientations. $\underline{V}$ lies along the projection of the true mean QRS vector (half area) in the eigenplane, and $\underline{W}$ is perpendicular to the eigenplane, oriented so that the rotation of the QRS loop in the eigenplane (about $\underline{W}$) is positive as defined by the right-hand rule. Finally $\underline{W}$ is chosen so that $\underline{U}$, $\underline{V}$, and $\underline{W}$ are pointed upward and form the polar vector (7-9). Also, the premise is that the V lead signal optimizes repolarization evaluation since it lies along the electrical axis of the heart. The individual eigenlead signals are presented to the cardiologist as in Figure 10. The temporal points, previously determined, are also indicated on these plots. The QRS and T loops in the eigenplane are displayed as shown in Figure 11.

The traditional planar tracings are displayed to the cardiologist as shown in Figures 12, 13, and 14. In these figures, the frontal plane is viewing the patient from the front (in the z direction), the sagittal plane is viewing the patient from his left side (in the minus x direction), the transverse plane is viewing the patient from the head downward (in the y direction). Each of these planar projections is scaled so that the loop being displayed fills a 5-cm square. The scale factor is a reference adjusted as illustrated in Figures 11-14. This is indicated by the size of the "+" symbols; as time increases, the symbols become larger. The interval between these symbols is 2.5 msec. Also shown on these planar views is the location (indicated by an asterisk) of the vectors prior to

the P wave. Since we have defined the origin of the coordinate system, or zero reference, so that the QRS loop starts from the origin, the heart vector prior to the P loop will not be the zero vector.

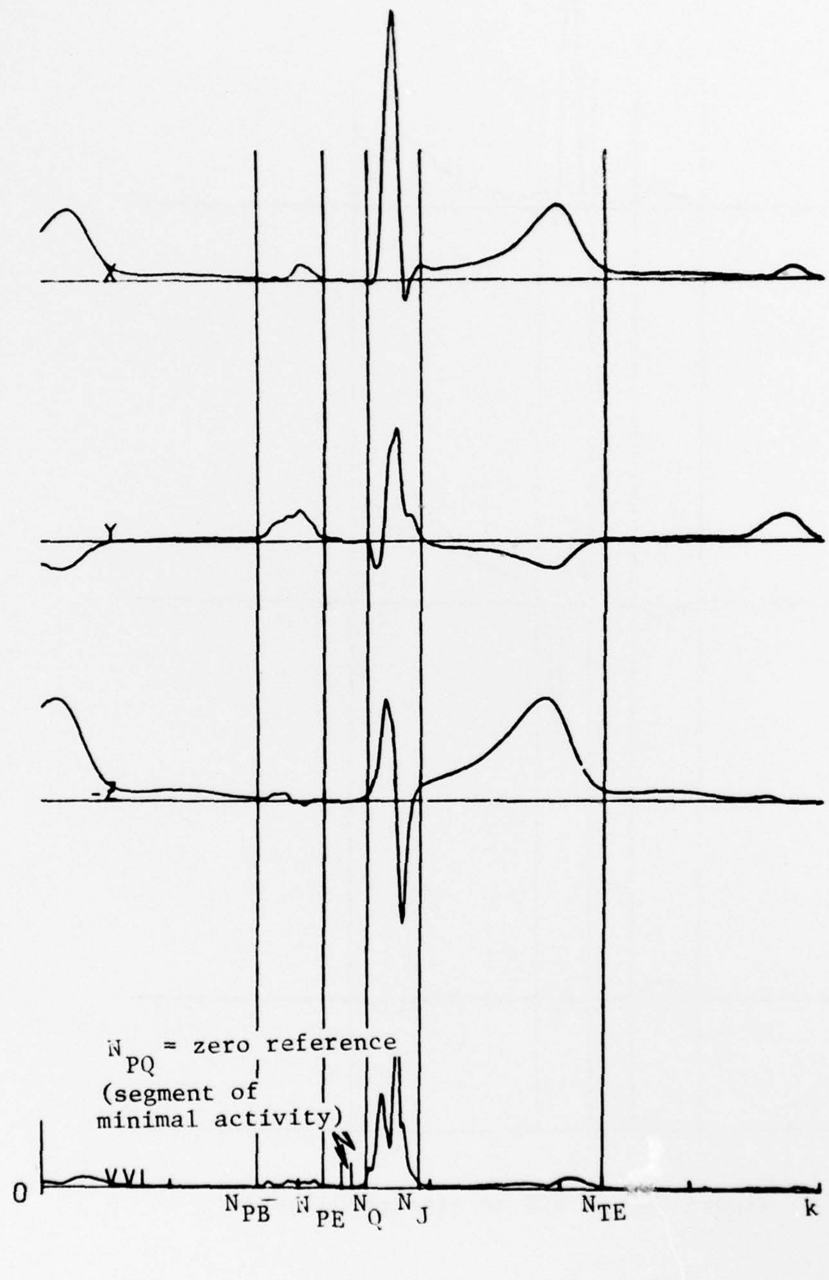


Figure 9. An example of the loop definitions.

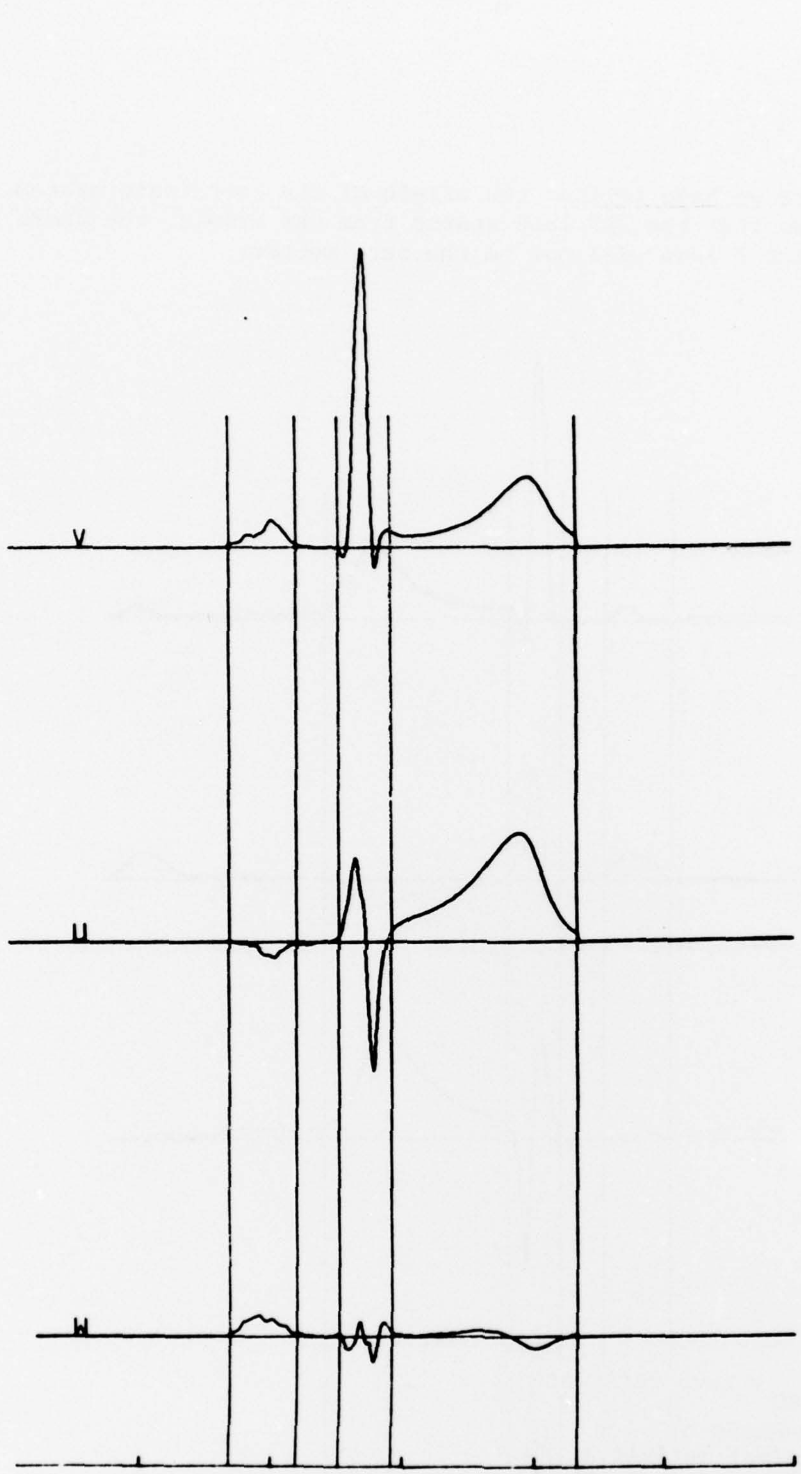
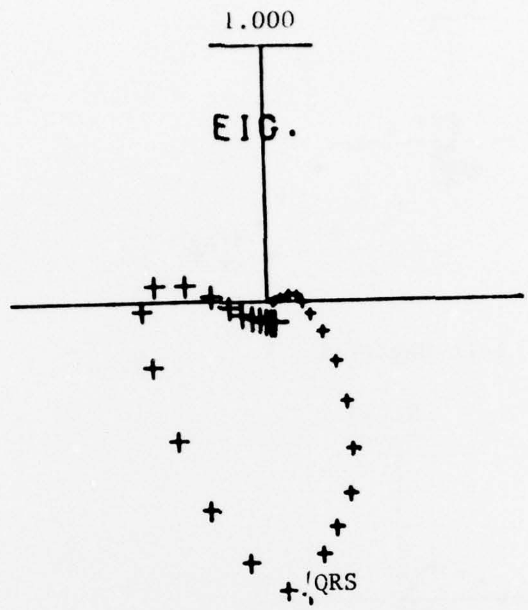


Figure 10. A VCG in eigencoordinates.



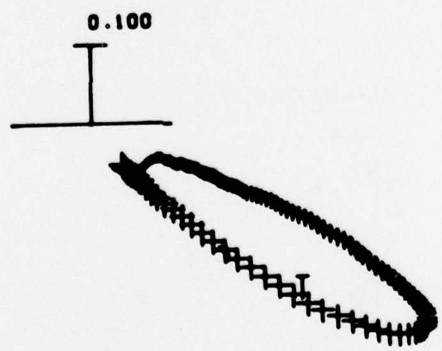


Figure 11. An example of the QRS and T loops in the eigenplane.

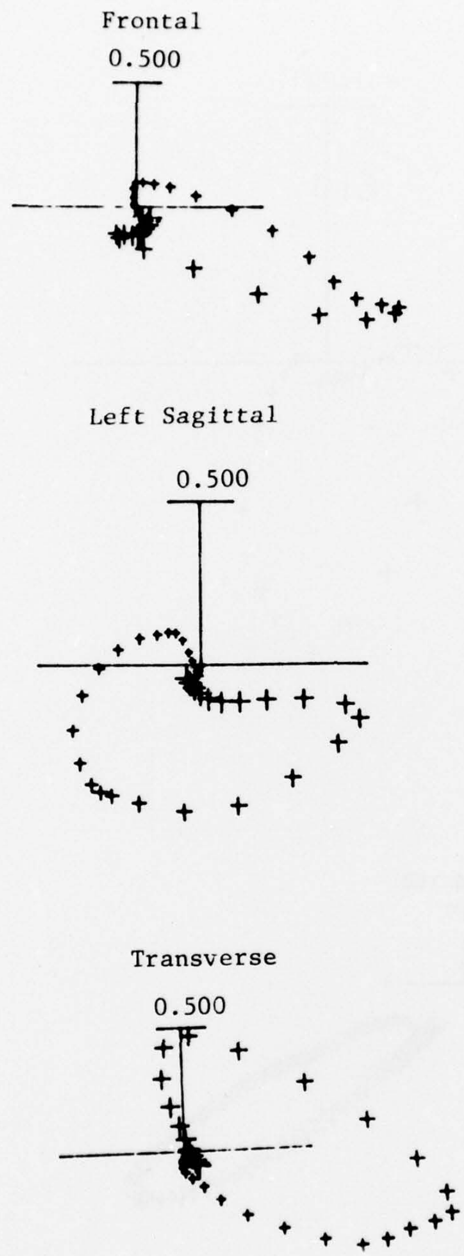


Figure 12. Planar tracings of frontal, left sagittal, and transverse QRS loops.

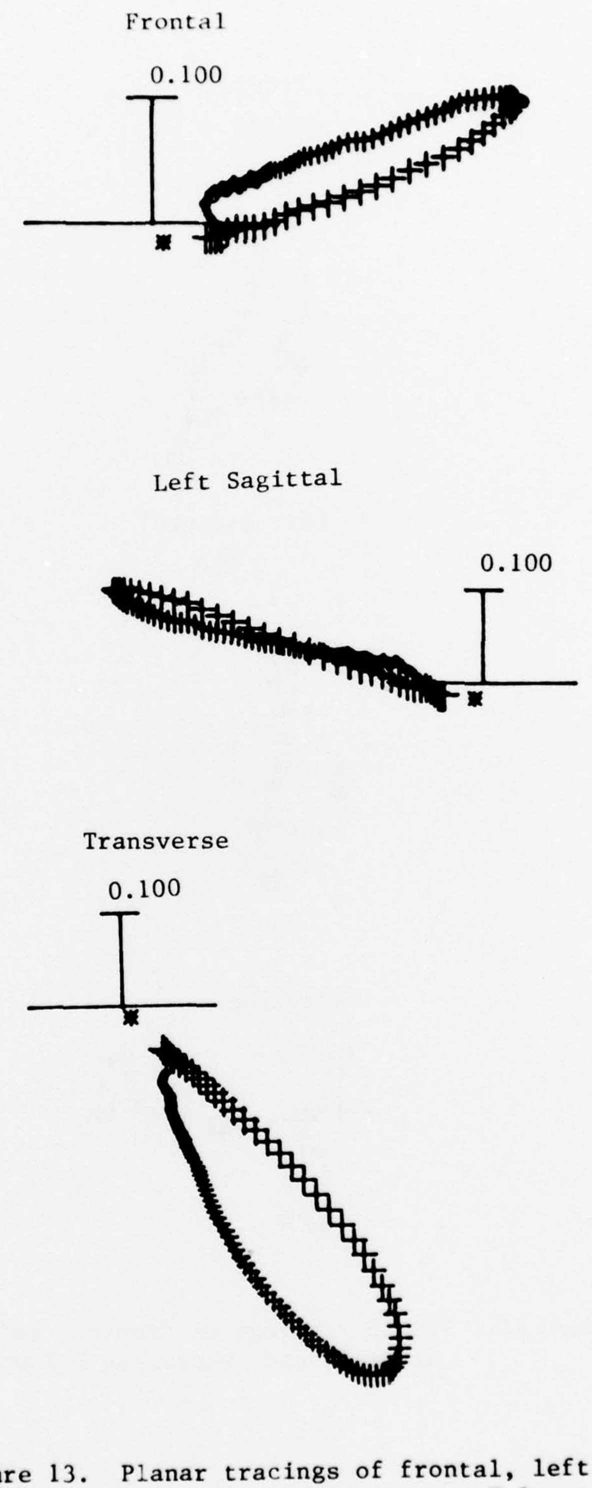


Figure 13. Planar tracings of frontal, left sagittal, and transverse T loops.

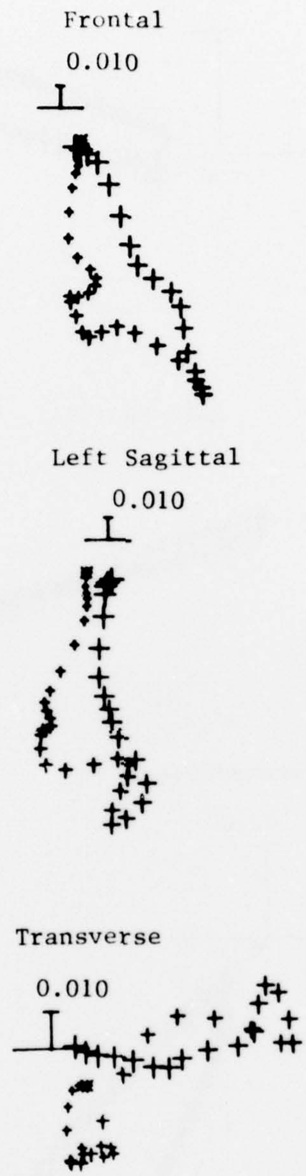


Figure 14. Planar tracings of frontal, left sagittal, and transverse P loops.

Finally, three vectors of importance to USAFSAM cardiologists are displayed as shown in Figure 15. These are (1) a vector designated J--the J-junction, $\underline{h}(N_J)$; (2) a vector designated M--the heart vector 40 msec (16 samples) after the J-junction, $\underline{h}(N_J+16)$; and (3) a vector designated T, which is 0.1 mV in length and with the same orientation as the maximum T vector. From the first two vectors (J and M), both ST depression and ST slope can be determined. The T unit vector is plotted to provide an indication of the relative positions of M and J to the maximum T.

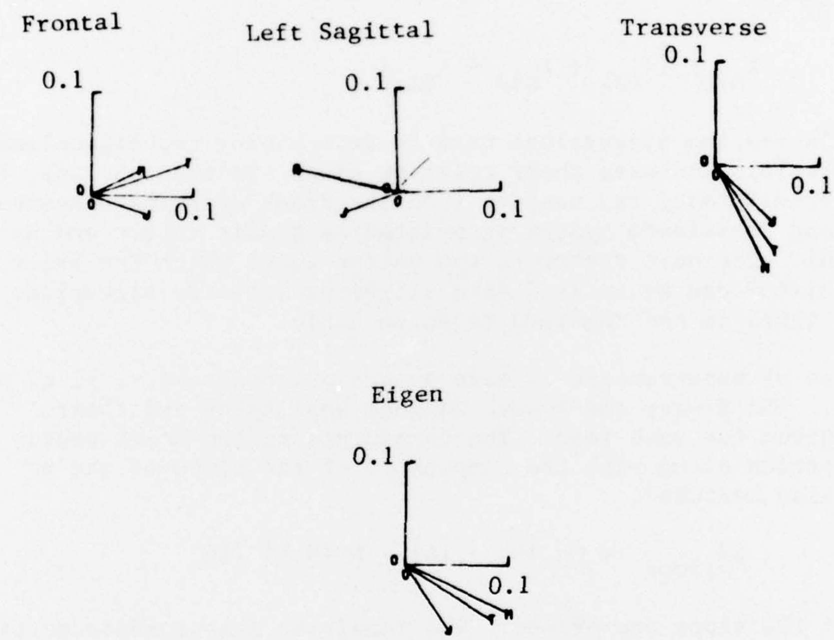


Figure 15. Planar J, M, and T vectors.

Printed Output

Along with the graphic displays described in the previous sections, three pages of computer-printed results are presented to the cardiologist. Figures 16 and 17 are examples of the first two pages--the basic data. On the first line, the VCG number identifies the patient. Although the computer algorithms were designed to be used on average beats (12), they can also be used on relatively noisefree individual beats. In each case,

the particular beat examined--1st, 2d, 3d, ..., or average--is identified on the first line of the printout; next, the patient's heart rate is given, based on the RR interval. The second line contains P, QRS, T, and QT duration times. These are derived from the temporal points previously defined.

$$\text{QT duration} = (2.5 \text{ msec}) (N_{TE} - N_Q)$$

$$\text{T duration} = (2.5 \text{ msec}) (N_{TE} - N_J)$$

$$\text{QRS duration} = (2.5 \text{ msec}) (N_J - N_Q)$$

$$\text{P duration} = (2.5 \text{ msec}) (N_{PE} - N_{PB})$$

The percent of out-of-eigenplane energy (3d-line display) is determined by

$$\lambda_{min} / (\lambda_{max} + \lambda_{mid} + \lambda_{min})$$

where the λ's are the eigenvalues used in determining the eigenplane, and the subscripts indicate their relative size. On the 4th line, the matrix for transforming the vectors from the Frank coordinate system to the eigenplane coordinate system is printed as a unit vector and an angle (theta). The unit vector is the vector about which the Frank coordinate system can be rotated into alignment with the eigenplane system, and theta is the required rotation angle.

A series of measurements is made on the preprocessed x, y, z, u, and v leads. The R-wave and T-wave maximum amplitudes and their ratios are given for each lead. The components of the heart vector at the J-junction along with the components of the slope of the ST vector are also measured.

$$\underline{ST}_{slope} = [\underline{h} (N_J + 16) - \underline{h} (N_J)] / 40$$

The units of the slope are mV/sec. The remaining measurements pertain to the vector loops.

A series of measurements is made that allow the cardiologist to examine the terminal forces (vectors) of the QRS loop. These are the heart vectors at 5, 10, 20, 30, and 40 msec into the loop, and 30, 20, and 10 msec from the end of the loop. To quantify how fast the vectors are moving, the average value of the lengths of the projections of the incremental vector into the four planes is determined for (1) the initial 30 msec of the QRS loop, (2) the time segment between initial and final 30 msec of the QRS loop, and (3) the final 30 msec of the QRS loop. These measurements--labeled MEAN ACT. 1ST, MEAN ACT. MID, AND MEAN ACT. LAST--are estimates of the mean magnitude of the projections of the velocity vector onto the four planes, where units are mV/sample.

VCG NUMBER 715717   BEAT AVG   HEART RATE = 70.6

P DURATION = 110.0   QRS DURATION = 117.5   T DURATION = 277.5   QT DURATION = 395.0 MILLISECONDS.

PERCENT OF OUT OF EIGEN PLANE ENERGY = 7.97

ROTATION VECTOR: X = -0.54; Y = 0.24; Z = 0.81; THETA = 121.

	X	Y	Z	U	V
SCALAR R WAVE	0.62	0.36	0.09	0.66	0.86
SCALAR T WAVE	0.07	-0.03	0.43	-0.19	-0.36
SCALAR T/R	0.107	-0.090	4.895	-0.288	-0.412
SCALAR J JCT.	-0.02	-0.03	0.09	-0.07	-0.06
40 MSEC. SLOPE	-0.64	0.77	0.83	0.25	-1.27

	FRONTAL	SAGITTAL	TRANSVERSE	EIGEN
5 QRS VECTOR	0.02	0.01	0.02	0.01
10 QRS VECTOR	0.09	0.05	0.10	0.01
20 QRS VECTOR	0.28	0.17	0.27	0.24
30 QRS VECTOR	0.57	0.61	0.69	0.73
40 QRS VECTOR	0.65	0.73	0.91	0.92
MEAN ACT. 1ST.	0.019	0.021	0.024	0.023
Q DURATION	5.0		12.5	10.0
YQ - ZR WIDTH	0.02	-0.01	0.13	0.01
YQ - ZR HEIGHT	-0.01			0.00
STD. QRS VECTOR	0.63	0.64	0.87	0.85
MAX. QRS VECTOR	0.68	0.75	0.94	0.93
MEAN ACT. MID.	0.022	0.026	0.019	0.028
-30 QRS VECTOR	0.57	0.52	0.29	0.58
-20 QRS VECTOR	0.40	0.38	0.14	0.40
-10 QRS VECTOR	0.16	0.16	0.04	0.16
MEAN ACT. LAST	0.019	0.018	0.012	0.021
J VECTOR	0.04	0.09	0.09	0.09
J DIRECTION	RS	SA	RA	
M VECTOR	0.04	0.12	0.13	0.13

Figure 16. Page 1 of printout.

M DIRECTION	RS	SA	RA	
MAX. T VECTOR	0.07	0.43	0.43	0.40
T/QRS VECTOR	0.099	0.576	0.463	0.435
MAX. P VECTOR	0.24	0.24	0.07	
5MS QRS ANGLE	-13.	-27.	25.	145.
10MS QRS ANGLE	15.	27.	27.	-2.
20MS QRS ANGLE	29.	129.	-24.	38.
30MS QRS ANGLE	36.	147.	-48.	40.
40MS QRS ANGLE	23.	160.	-49.	51.
TRUE QRS ANGLES	-29.	-149.	-42.	90.
STD. QRS ANGLES	-15.	-165.	-46.	70.
MAX. QRS ANGLES	-42.	151.	-48.	56.
-30MS QRS ANGLE	-63.	-105.	-27.	129.
-20MS QRS ANGLE	-71.	-95.	-13.	141.
-10MS QRS ANGLE	-91.	-75.	94.	168.
J - M ANGLES	-62.	19.	9.	21.
MAX. T ANGLES	11.	1.	96.	-118.
QRS-T ANGLES	53.	-150.	144.	-174.
MAX. P ANGLES	84.	98.	-3.	

Figure 17. Page 2 of printout.

Measurements labeled YQ-ZR WIDTH and YQ-ZR HEIGHT relate to the QRS loop and are defined as follows. In the frontal plane, YQ width is the maximal-initial-left-superior force, the value of x at the end of the Q wave in y (y = 0); in the left-sagittal plane, the maximal-initial-superior-posterior force, the value of z at the end of the Q wave in y (y = 0); in the transverse plane, the maximal-initial-left-posterior force, the value of z at the end of Q wave in x (x = 0); in the eigen-plane, the value of u at the end of the Q wave in v (v = 0). In the frontal plane, height is the maximal-superior-initial force (YQ height); in the eigenplane, the maximum amplitude of the Q wave in v. Examples of these measurements are shown in Figure 18.

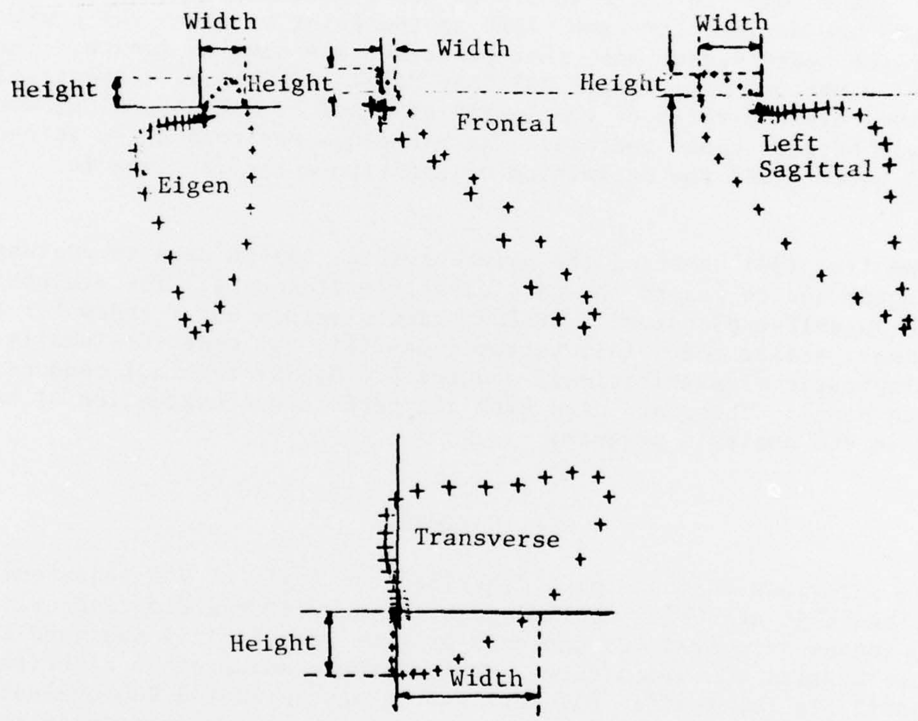


Figure 18. Examples of the height and width measurements in various planes.

The J, M, and T vector lengths and orientations are presented (Figs. 16, 17) with the following exception. Instead of giving the angular location of the J and M vectors in the planes, only the quadrant in which they are located is given. For example, RS signified rightward and superior. Also, angles between the projections of J and M onto the four planes are given. The reference for measuring the angles is the J projection, and positive rotations are defined in Figure 6.

The usual (STD) and maximum QRS vectors' lengths and orientations are printed (Fig. 16) with only the orientation of the true mean QRS vector given.

The values of the projections of the heart vector at the peak of QRS, T, and P loops in the four planes are given, where the peaks of the loops are defined for each plane as the point at which the projection of the heart vector onto that plane has its maximum length. These projection vectors are labeled MAX.QRS, MAX.T, and MAX.P, respectively. Also given are the ratio of the length of MAX.T to MAX.QRS, along with the angle between these vectors. The reference for this angle is the MAX.QRS vector, and the definition of positive angle is given in Figure 6.

The last (3d) sheet of the printout (Fig. 19) is used to evaluate the program and to record the cardiologist's diagnosis. The evaluation section is self-explanatory. USAFSAM cardiologists enter codes for the following: scalar codes (A), vector codes (B), SSI code (C--*locally* used diagnostic classification), and the T.C.D. (D--terminal conduction delay in msec). These are used with the performance evaluation of an automated VCG analysis program.

APPLICATIONS

The previous sections have described the logic of VCG measurement algorithms that are being applied to a set of vectorcardiograms used in developing an automated VCG analysis program specifically designed for the USAF Central ECG Repository. Most of these measurement algorithms are applicable for routine clinical use in any automated VCG evaluation program. Several of these algorithms (e.g., the determination of the eigenplane and its spatial orientation) were developed for investigations designed to identify potentially unique diagnostic features of the VCG. The algorithms can be readily modified for widespread application in many electrocardiographic analysis programs.

VCG NUMBER 715717 AVG

1 NOISY:	1-YES	2-NO					
2 QRS BEGINNING:	1-ACCEPTABLE	2-EARLY	3-LATE	4-ACCEPTABLE EARLY	5-ACCEPTABLE LATE	MSEC.	X Y Z 3
3 QRS ENDING:	1-ACCEPTABLE	2-EARLY	3-LATE	4-ACCEPTABLE EARLY	5-ACCEPTABLE LATE	MSEC.	X Y Z 3
4 P BEGINNING:	1-ACCEPTABLE	2-EARLY	3-LATE	4-ACCEPTABLE EARLY	5-ACCEPTABLE LATE	MSEC.	X Y Z 3
5 P ENDING:	1-ACCEPTABLE	2-EARLY	3-LATE	4-ACCEPTABLE EARLY	5-ACCEPTABLE LATE	MSEC.	X Y Z 3
6 T ENDING:	1-ACCEPTABLE	2-EARLY	3-LATE	4-ACCEPTABLE EARLY	5-ACCEPTABLE LATE	MSEC.	X Y Z 3

A SCALAR CODES:

```
1 XYZ:     (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____)
  FRANK       1       2       3       4       5       6       7       8       9      10      11      12

2 12 LEAD: (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____)
              1       2       3       4       5       6       7       8       9      10      11      12
```

B VECTOR CODES:

```
           (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____) (_____)
              1       2       3       4       5       6       7       8       9      10      11      12
```

```
C SSI CODES: (_____) (_____) (_____) (_____) (_____)

  T. C. D.   (_____)
```

Figure 19. Cardiologist review sheet (page 3 of printout).

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Obtaining measurements from patient vectorcardiograms is a tedious and time-consuming procedure. This report describes a computer-assisted method to derive the interval amplitude and angular measurements used by vectorcardiologist to evaluate a patient vectorcardiogram. The computer also prepares graphic displays which have much better resolution than the conventional Polaroid photographs. All measurements are made on the same beat rather than having each planar projection and loop from a different beat as in the photographic method.

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